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Space Technology – A Study of the Significance of Recognition for Innovators of Spinoff Technologies

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A Case Study on the Impact of the Space Technology Hall of Fame Award

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2860 S. Circle Drive, Suite 2301
Colorado Springs, CO 80906
Telephone: (719) 576-8000 FAX: (719) 576-8801

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Abstract

This report represents the preliminary effort in studying the significance of recognition for innovators of spinoff technologies. The purpose of this initial year's effort in this area was to gather preliminary data and define the direction for the remainder of the research.

This report focuses on the most recent recipients of the Hall of Fame Award, the developers of liquid-cooled garments. Liquid-cooled garments technology and its spinoffs were used as a case study to define and explore the factors involved in technology transfer and to consider the possible incentives in developing commercial applications including the Hall of Fame Award. Through interviews, views of award recipients were obtained on factors encouraging spinoffs as well as impediments to spinoffs.

The researchers observed complex inter-relationships among the significant entities (government, individuals, large and small business,), the importance of people, the importance of resource availability, and the significance of intrinsic motivation; drew preliminary conclusions pertaining to the direct and indirect influence of recognition like the Hall of Fame Award; and planned the direction for next year's follow-on research.

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Introduction

The impact of the research, development, and technologies resulting from the space program can be measured in several ways. One mechanism is the direct impact the R&D dollars make on the adjacent community. For example, in Huntsville, Alabama, where the Marshall Space Flight Center is located, an economic impact of over three times the Center's annual budget has been identified. This is the tangible impact of direct purchasing power. In addition to this there exists a significant intangible impact such as improved schools, cultural and civic improvements and other individual contributions to the community.

Not quite as clear is the impact that NASA R&D has on society as a whole--in companies and communities throughout America. Of particular interest is the impact of secondary applications of space technology. These applications are now referred to as "Spinoffs" and result from the transformation of a space-intended technology to a terrestrial application (e.g. scratch-proof lenses resulting from a commercial use of coatings prepared for space visors). This spin back into the economy multiplies the value of the government's investment in space.

In the Space Act of 1958, language was inserted mandating that NASA "...disseminate as broadly as possible the results of its space research...." This requirement was implemented through program initiatives to effect technology transfers. In 1963, NASA established Technology Utilization Offices at each of its R&D Centers and complemented them with outreach capabilities to businesses through an independent set of organizations known as Industrial Applications Centers (IACs). This became the nation's first comprehensive infrastructure for facilitating the movement of Federally sponsored R&D to the broad U.S. marketplace.

Studies and reports to characterize and document the approximate economic impact of these spinoffs have been done by the Denver Research Institute and more recently the Chapman Research Group (CRG). Since the mid 1970s NASA has published an annual document entitled Spinoff which provides vignettes of selected technologies that have been commercialized.

While these efforts have been important and have contributed to a general awareness and understanding of spinoffs, they have not yielded **methodologies** that could enhance the development of successful spinoffs and identify and promote their value to businesses and the general public (both space and non-space advocates).

During the past 30 years as NASA has conducted its technology transfer programs, it has gained considerable experience--particularly pertaining to the processes. Three areas that have not had much scrutiny are the examination of the contributions of the individuals who have developed successful spinoffs; the commercial success of the spinoffs themselves; and the degree to which they are understood by the public. In short, there has been limited evaluation to measure the success of technology transfer efforts mandated by Congress. To date no model exists that enables one to select R&D activities that will be the foundation of successful applications that achieve wide recognition by the American public. Deriving a quantified model is difficult because there is no doubt that entrepreneurship and serendipity play major roles. However, as all scientists and engineers know, serendipity occurs more frequently under planned circumstances.

Therefore, this research is designed to examine, over three years, a unique set of individuals and technologies to ascertain and extract from these cases various factors that might assist in enhancing the technology transfer process. The research effort is based on the hypothesis that an important motivator is adequate public recognition of innovators for their accomplishments. The hypothesis is coupled with the corollary that greater promotion of successful space spinoffs through easily understood and educational approaches will enable the spinoff process to be more effective.

This report represents the preliminary effort in studying the significance of recognition for innovators of spinoff technologies. The purpose of this initial year's effort in this area was to gather preliminary data and define the direction for the remainder of the research. This report was written by Dr. Robert N. Ewell, research project director, and Dr. Darwyn Linder. We received guidance from US Space Foundation Executive Director, Jack Flannery, and specific help, especially in identifying and contacting recent spinoff innovators, from Dr. Timothy Janis, Director of the Aerospace Research Applications Center (ARAC).

Background

During the past five years, the U.S. Space Foundation, in cooperation with NASA and ARAC, has identified and recognized many significant spinoffs. These have been selected by independent review panels of prominent Americans and those selected have been inducted into the Space Technology Hall of Fame (HoF). The induction is a significant event of the National Space Symposium and results in the national, public recognition of government and industry individuals and organizations directly involved with developing a technology and applying it in the commercial sector. Therefore, this process has enabled the Foundation and ARAC to build a database containing a number of key innovators. This database will be a primary resource for this study.

The primary research objective this year was to propose methodologies by which to determine to what degree recognition such as the Hall of Fame Award is a significant factor for NASA success in carrying out the Congressionally-mandated transfer of space program technologies to American industry.

Methodology

We focused our research effort this year on the most recent recipients of the Hall of Fame Award, the developers of liquid-cooled garments. We used the liquid-cooled garments technology and its spinoffs as a case study to define and explore the factors involved in technology transfer and to consider the possible incentives in developing commercial applications including the Hall of Fame Award.

We began by examining a brief history of the liquid-cooled garments technology written by ARAC (see Appendix A). Using the history as a guide, we developed the following interview format. Lead (general) questions are in bold face with follow-on questions listed after. Questions are not necessarily listed in the order they were asked--the questions were simply a guide to the interviews.

To what extent would the possibility of recognition such as the Hall of Fame influence the selection of research projects, project priorities? In what ways would the recognition affect your professional activities?

What were some of the factors that lead to the liquid-cooled garments project?

Did the possibility of Hall of Fame-like recognition influence your selection of the liquid-cooled garment project? If not, would it today?

To what extent are you aware of previous developments in the technology when you start your research?

To what extent are you aware of parallel developments in the same technology at the same time?

For example, both JSC and Ames were both working on liquid-cooled garments. Was there any connection between the two efforts?

Can you explain the process by which space technology is developed into spin-off commercial applications? What are the features, critical junctures, or decisions?

As you were working, did you envision any of the applications that would follow?

For example, Who spurred ARC into looking for spin-offs? What was the incentive to look for spin-offs? How was Accurex selected? Where did the liquid-cooled helmet liner concept come from? Who said there was a need?

Why did ILC-Dover produce a commercial version of the liquid cooled garment? What motivated the other applications?

Why was ARC involved with race-car drivers? Who at ARC made the connection?

Why did JSC scientists study a scalp-cooling system?

Who at LSSI got them involved in cooling garments for children? Why?

How is the database of projects/ technologies maintained and accessed so that the information gets out?

For example, by what mechanism were calls by private citizens to JSC and the Langley Research Center routed to the right people/companies?

What are the most important factors in moving from space technology for space to spin-off commercial applications? Recognition? Specific contract/tasking for military non space applications? Entrepreneur vision? Good idea? Risk to develop? Initiative?

For example, who founded LSSI from Accurex? Where did the ideas for his applications come from? What was his incentive?

Are you familiar with NASA Spinoff, published annually by NASA? How thoroughly/ often do you read? What do you learn from the book(s) about the process of developing spin-offs from space technology?

We asked Dr. Janis to identify key people within the key organizations, Ames, Johnson, Langley, ILC Dover, and LSSI. We planned to ask the interviewees questions appropriate for their position, supplementing general questions with specific-instance questions. Dr. Janis provided five contacts of which we were able to interview four plus one that we added. The five will be referred to as follows:

Chief Executive of a large aerospace company. (Liquid-cooled garments constitute less than 2 percent of business.)

President of a small manufacturer of liquid-cooled garments.

Engineer, NASA Johnson Space Center. (We will refer to him as an "operational engineer" since NASA Johnson is directly concerned with launching people into space.)

Engineer, NASA Ames Research Center. (We will refer to him as a "research engineer.")

Medical researcher and research manager, NASA Ames.

Dr. Linder and Dr. Ewell jointly interviewed all the people on the list. Each interview was preceded by initial contact by Dr. Ewell to establish a time for the interview. The interviewees were then faxed a general overview of the research project (see Appendix B for a sample) and a copy of the interview questions as shown above.

The interviews were carried out by means of AT&T teleconferencing on December 1, 7 and 8. Each conversation lasted about an hour. The conversations were not tape-recorded, but Dr. Linder took hand-written notes, and Dr. Ewell summarized the conversations as they were in process using computer-based word processing.

Findings

The mix of interviewees formed an excellent base for diverse viewpoints on the technology transfer process.

The following is a synthesis of the major points made by the interviewees.

Information Sharing

- Overall, everyone was aware of what other agencies were doing with respect to the liquid-cooled garments. The medical researcher came to Johnson Space Center to participate in the development of the Apollo suit and from there went to NASA Ames. Therefore, the technology was well known to both centers even though their approaches to body heat transfer diverged.

- Information is also known to the Technology Utilization Offices at each NASA center. Calls coming in to them were referred to an appropriate office.

Factors encouraging spinoffs

What motivated the transition of technology from space use to commercial use? How were non space applications discovered and developed?

There were a variety of most interesting perspectives on these questions--the central issue of this research. Following is a composite of factors given. Following the list is a table listing the factors, the perspective from which the observation was made, and a summary or paraphrase of what the interviewees said. The absence of explicit comments for certain factors from some of the interviewees does not necessarily mean they would not support those factors. The factors are not listed in any particular order.

Summary of factors encouraging spinoffs

1. NASA support of its engineers
2. Outside requests/challenge of a problem
3. Creativity
4. NASA support to industry
5. National Interest
6. Pride and enjoyment of meeting a need
7. Profit
8. Recognition

Factors encouraging spinoffs

Factor	Comments
- Source	
1. NASA support	
- NASA operational engineer	<p>Spinoffs are part of NASA's charter. e.g. David the bubble boy. "We're here to serve. We can't work for an individual, but we can work with institutions."</p> <p>Management is interested in dual-use technology. System reacts to management interest, and we think about spinoffs even though our primary mission is to put people in space--not solve other problems. We are required to publish our work and receive \$50 when we write an article for the NASA Tech Brief.</p>
- NASA research engineer	<p>Technology transfer is politically correct. We work to our mainline NASA mission: to develop equipment for harsh environments. However, we have expertise and are not tied to a bottom line as a company is. When people call, we can work a little on problems without a formal requirement. Essentially, a little discretionary time is funded by my salary. In addition, the Technology Utilization Office at Ames had a little money at one time to which we could charge research/prototyping. When a need came along, say a kid in a wheelchair, we could put together a proposal.</p>
- NASA medical research manager	<p>I encouraged engineers to apply the technology outside NASA because I knew there would be many applications and that it would help NASA's case before Congress.</p>

2. Outside requests/challenge of a problem

- NASA operational engineer

The original scalp cooling system was for a NASA division chief's secretary who, after she retired, developed cancer. Her husband developed the Cool Head and marketing.

In another case, we were called by a man who was literally freezing, stringing wire on a pole in Alaska. We referred him to our contractor.

- Small company president

We were tasked to develop the helmet liners for helicopters in Viet Nam.

- Large company executive

We built the first commercial application outside NASA in 1970 which was for people in refineries and other places who needed to work in long term heat environments.

- NASA research engineer

We like a "good, intriguing problem." Engineers have a little MD in them.

Someone called Langley about the children born without sweat glands-- Hypohidrotic Ectodermal Dysplasia (HED). Problem was referred to us.

A child in Crippled Children's Hospital in Ontario had erythromelalgia a disease with unknown cause which results in needing to keep skin cool, usually in water or snow. Results in gangrene and amputation. A doctor called NASA who put them in touch with us. We had to bootleg the money to start work. We built liquid-cooled Bermuda shorts and a supporting cart.

Work followed the people. Many solutions were driven by personal contacts and personal initiative.

3. Creativity

- NASA research engineer
One of us had the idea that people in hot environments could use liquid-cooled helmets. This resulted in the application to helicopter pilots in Viet Nam.
- Large company executive
We got into the space suit business when some engineers in our company who were interested in space realized that Mercury, Gemini suits wouldn't work for Apollo. They developed on their own the technology which resulted in our winning the contract.
- NASA medical research manager
We always had ideas "cooking in the hopper." We knew there were people working in hot conditions, so we looked for creative ways to apply the technology. We had the idea to apply the technology to race car drivers (now used by over 500 drivers). We also suggested application to industrial furnaces.

4. NASA support to industry

- NASA research engineer
We worked with a contractor to implement a concept from the Bureau of Mines--coal miners and coal mine rescue people. They had 6-8 hours of air but no cooling system. The contractor produced the liquid-cooled patches. The Bureau of Mines had the requirement but NASA supplied the money.

In another case, a call for help from a doctor resulted in NASA funds being channeled to the liquid-cooled garments contractor. The (small) contractor couldn't do it without funding, and the doctor/patient did not have the money required either. Without NASA support, this prototype project couldn't have happened.
- Large company executive
[A different perspective] We didn't want or need NASA financial assistance to go commercial. We were afraid NASA would want "a piece of our action" or want R&D reimbursement.

5. National Interest

- Small company president
In 1973 when oil embargo hit, people became aware of the limited number of resources we have on "spaceship earth". I felt we should apply space knowledge to real-world problems. In this case, we could micro-cool the individual working in a high-heat environment rather expend energy to try to cool the entire area. Primary applications were in glass plants, nuclear power plants, and petrochemical plants.

6. Pride and enjoyment of meeting a need

- Small company president

I was very proud of one of our applications. We provided garments to a military decontamination team working on a tropical island. Our suits enabled them to work four hours at a time instead of just a few minutes.

Once I saw someone on the Today show that needed the helmet. I contacted the individual....

7. Profit

- Small company president

We are constantly looking for applications. I have sales representatives actively working in the medical, military, and industrial communities.

- Large company executive

In the early days, we didn't do sophisticated market research. We just tried to envision the need so we could diversify into the market.

Our real impetus was to maximize return on achieved development activity. We can't say we applied the technology for patriotic or scientific reasons. Today we do immediate market research rather than rely on emotionalism as we did earlier.

8. Recognition

- NASA operational engineer

Hall of Fame recognition was "great". Private sector recognition is rare for government employees. I acted as recipient for our Center and shared the experience with the division. The recognition was "about time"--it's overdue when it comes. I don't think the award would change anything on future projects.

Recognition has no bearing on the spinoff process. We work to requirements. Spin-offs are OK but not a driver. Neither would recognition. We do get peer recognition with publications. Someone got a \$10,000 check from government for developing something used in fire fighting equipment.

- NASA research
engineer

I had to be asked to go to the Hall of Fame presentation. "That kind of thing is not terribly important to me."

Innovation is intrinsically motivated; however, awards like the Hall of Fame matter to the younger people. I pass projects around to other engineers. They get excited about working on something like that. If they get awards, then their supervisor can use the award to give internal awards.

The Hall of Fame award is the only recognition I've ever had.

- Small company
president

"Proud" to receive a letter from the NCO association for the project involving the decontamination team in the tropics.

I was "proud and honored" to receive the Hall of Fame Technology Award. However, the experience was bittersweet. There was not enough press--not enough public exposure. Disappointed that my professional life was almost entirely involved with space suits but only the tail end was recognized. We use the honor in our publicity. There is no professional impact to the award.

- Large company
executive

The Hall of Fame Award was well done. I didn't know anything about the award until I was invited to go. I didn't even know about the symposium. I was impressed--lots of people, all the major players. The stage, etc., was impressive.

One of our folks who's done a lot for the space business was recognized, but not for what he's done. [i.e., recognized for the commercial application rather than the actual work on the Apollo suit.] His receiving the recognition did partially enable a "really decent retirement" later at Houston.

There isn't much recognition in the business although the astronauts do come to the plant sometimes for the production workers. Scientists and engineers do not worry about non-recognition--they are intrinsically motivated.

The Hall of Fame award doesn't work for recognition because no one knows about it.

- NASA medical
research manager

All awards are factors in the process for different people.

Recognition is important. In Japan, technology transfer people have more recognition from peers and the public. In our society, it should come from the top--the Presidential and Congressional level.

Impediments to Spinoffs

The interviewees also revealed factors they considered impediments to the spinoff process. Following the summary list will be a table similar to the one for factors encouraging spinoffs, summarizing what the interviewees actually said.

Impediments

1. Not enough NASA support or PR
2. Not enough tech transfer funding
3. Too much separation between government and industry
4. Difficulties unique to the medical community

Impediment

Comments

- Source

1. Not enough NASA support or PR

- NASA research engineer

A better technology than liquid-cooled garments is the MAST suit--mobile, anti-shock trousers--carried by every ambulance around the world. The suit has bladders like a g-suit to redistribute blood. It started when a couple guys took it over to Stanford and used it on a woman who was in shock after surgery, and she lived. A case study was written and published in the Journal of the American Medical Association. The NASA connection has never been publicized. Half dozen companies make it, and no one knows how it [the technology transfer] happens.

- Small company president

Sometimes the word does not get out very well. Initial success should be nurtured with NASA support. For example, in 1974, we made our first Multiple Sclerosis contact at UCLA through NASA. The intervention was a success but nothing happened until the HED project came to the forefront in the late 1980s. Payoffs would be better and faster if the TUOs played a more active role, nurturing the technology, encouraging more clinical trials, engaging in PR.

I was involved with the Richard Petty head liner. NASA invited us to the research center. We provide the garment to over 500 race car drivers. Petty said it extended his career 5-10 years. But all the PR has gone to the flame retardant suits and none to the liquid-cooled suit.

2. Not enough tech transfer funding

- NASA research engineer

Technology transfer should be funded and available without "strings", so that when a problem comes in, we can write a quick proposal and get the money.

3. Too much separation between government and industry

- NASA medical research manager

I don't think we're set up in this country in an optimum way to encourage spin-off applications. There is too much separation between government and industry. The Japan, Inc. concept is better. How far is government willing to go to encourage and fund research? Today, government is concerned only about the initial mission, e.g. Apollo. Both government and industry need to move to close the existing gap. For example, SBIR (Small Business Innovative Research) is a great program. University-based centers are also moving in the right direction. However, there's more rhetoric than money being put into this concept.

4. Difficulties unique to medical applications

- Small company president

There is a long "gestation" period for medical applications. It takes a long time between discovery and wide-spread application.

- Large company executive

We tried medical applications once, but we couldn't make a business out of it. There were applications for individual cases, but we couldn't get into mass production. The doctor community doesn't work like others. A testimonial by one doctor won't necessarily be accepted by others due to competition for recognition and discovery. In addition, doctors won't pay for R&D.

- NASA research engineer

There's not enough medical market for companies to get into it. There are lots of ideas, but any one may affect only 100 kids per year. However, one such idea, not developed for that reason, could have been used today for AIDS victims.

Conclusions, Recommendations, and Directions for Further Study

This case study of the development of commercial spinoffs from the liquid-cooled garment technology has allowed us to develop several potentially important hypotheses about the process by which possible applications are identified, explored, and implemented. Our task was to assess the role of Hall of Fame recognition in that process. However, to put that role into perspective it is necessary to examine several other features of the process.

Observations

- Complex inter-relationships among entities

The first observation to be drawn from this case study is that the roles of government, non-profit institutions, private corporations, and of the individuals who work within all of those settings are interrelated in a quite complex way. As applications of the liquid-cooled garment technology were developed, the role of NASA was seen by some as not supportive enough, and by others as potentially negative. It may be that small, entrepreneurial efforts require more support from NASA, while larger corporations require assurances that licensing and patent issues will not restrict profit. The roles of NASA engineers in finding potential applications and developing prototypes were important, and their contributions may not have been possible had rigid job descriptions been applied. They responded to challenges offered by individuals, often private citizens, who had problems that they thought NASA could perhaps solve. Private citizens, physicians, and people in highly specialized jobs or environments played an important role in identifying potential applications. Often, they were unaware of the specific technology, but thought that NASA might have an answer to the problem. The role of TUOs in directing those inquiries to the appropriate Center or person was very important. The NASA engineers were not, however, simply reactive in this process. They were on some occasions proactive, initiating inquiries into the feasibility of an application. Individuals in the private sector contributed both to the development and refinement of the technology, and to the development of new applications. In this case, then, there were not clearly delineated, mutually exclusive roles for government, the private sector, or for the persons involved. Additional cases must be examined to determine whether this pattern is typical of successful technology transfers, represents but one of several patterns, or was a unique instance.

- Importance of people

A second observation is that the development of applications is driven primarily by bringing the right problems to the right people. In this case study, problems were identified in the medical realm because the developers of the technology were trained in medicine and physiology. They knew where to look and could determine whether it would be possible to adapt liquid-cooled garment technology to solve the problem. In this case, physicians and physiologists were necessarily involved in the mission-oriented development because of the nature of the problem to be solved. It will be important to determine whether other technologies have been applied in areas beyond the expertise of the original developers. It may be important to establish a process in which NASA technologies are reviewed by specialists in many different disciplines to develop hypotheses about potential applications.

- Importance of resource availability

A third observation is that resources of time and funding were important, within NASA as well as in the private sector. It is not sufficient to bring the right problem to the attention of the right people. They must have the time and resources to design, prototype and test an application. Some NASA facilities are uniquely configured to support this process. However, the technical and scientific staff must have time available for these activities, and they must be able to use the resources of NASA centers to do the bench work and field testing. In the private sector, especially in small enterprises, persons able to solve the problems must be supported so that the time and facilities are available, while the enterprise can continue to be financially viable. This implies a continuing role for government in fostering the development of application, even after the technology has been transferred to the private sector.

- Significance of intrinsic motivation

Finally, we repeatedly observed that the process of developing innovations was intrinsically motivated. Engineers are problem solvers, and an intriguing problem that may be solved with a newly developed technology is a nearly irresistible challenge. We also observed that engineers, R&D managers, entrepreneurs, and corporate executives were aware of the need to develop terrestrial applications of space technology, as part of the overall mission of the space program. They often said that it was the "Right thing to do." However, a general mission orientation is a nonspecific motivator. In most instances, the application of liquid-cooled garment technology advanced because a specific problem was presented to people who saw it as a fascinating challenge.

Preliminary Conclusions on the Role of Recognition

- Direct Influence

What, then, was the role of recognition, and specifically of Hall of Fame recognition in the spinoff of liquid-cooled garment technology? It appears not to have been a primary motivational factor at the time people were actively developing applications of liquid-cooled garment technology. However, all of our interviewees said that the Hall of Fame award was greatly appreciated, that it was an impressive event, and that they had been able to use it in some manner, although it did not contribute to personal advancement for these individuals. From a psychological perspective, an award so far removed in time from the work it recognizes cannot be the primary reason for doing the work. The intrinsic value of the work, and the immediate reward of finding a solution to an acute problem appear to have been the major motivators in this instance. However, liquid-cooled garment is a technology development that was initiated some 30 years ago. Perhaps technologies initiated more recently, after the advent of the Hall of Fame, or in a period of time when the space program was in need of additional justification, would show more evidence of being facilitated by the prospect of Hall of Fame recognition. Certainly, more than one case study is needed to assess the impact of the Hall of Fame on the technology transfer process.

- Indirect Influence

Hall of Fame recognition may also play a less direct, but very important, role in the development of technology applications. The history of a successful transfer, as in the case of liquid-cooled garment technology, may make clear to others the requirements for a successful spinoff project. In our quite detailed study of the liquid-cooled garment case, we became aware of many requirements, many sources of support, and many impediments in the technology transfer process. If these insights are confirmed in additional cases, or if other patterns emerge that can be systematically related to certain classes of technology, potential spinoff developers will be able to plan efforts that have a higher probability of success by following the models provided by Hall of Fame recipients. If this role of Hall of Fame recognition is to be fulfilled, the process of spinoff development, as well as the resulting products, must be reported and widely disseminated in the recognition process.

Directions for Further Study

- Value of interview methodology

This pilot project has confirmed the value of an interview method, and a case study structure for the research effort. We found the respondents to be very forthcoming in answering our questions. They were willing to take the time for the interviews, and they seemed to enjoy the process. We believe that we were able to develop a much more informative account of the spinoff process than would have been possible on the basis of a questionnaire study. It is now necessary to develop similarly detailed accounts of other application programs, with the goal of finding one, or several, process models. It is necessary to explore the role of Hall of Fame recognition in other successful spinoff projects, to determine whether it has been a direct motivator, or has some other function in the process. It will also be necessary to broaden the research effort to include the professional and consumer communities that use spinoff products. Hall of Fame recognition of a spinoff may encourage such communities to look for solutions to problems they encounter in the technologies developed for the space program, posing more of the kind of intriguing problems that appeared to be important in the development of liquid-cooled garment spinoffs.

- 1994 research plan

Our research plan for 1994 will include two main data gathering efforts. We will refine the interview schedule used this year, and attempt to collect interviews from a broad array of Hall of Fame recipients. We will identify professional and consumer communities that have adopted or benefited from spinoffs, and develop questionnaires to assess the knowledge they have of the spinoff process, and part they may have played in posing problems or identifying needs that stimulated spinoff development. Analyzing these data, we will attempt to construct one or several templates of the spinoff process. We will continue to assess the role of Hall of Fame recognition in facilitating technology transfer, both as a direct motivator for innovative applications, and as means of disseminating the processes by which successful transfers are achieved.

Appendix

Liquid-Cooled Garments

"A Brief History"

LIQUID-COOLED GARMENTS

"A Brief History"

BACKGROUND

The first liquid-cooled garment was designed in the 1950's in the Royal Air Force. A prototype was built at the Royal Aircraft Establishment in Farnborough, England. Under the direction of Dr. John Billingham, a group of British scientists and engineers assimilated technologies from many different sources to develop the first liquid-cooled garment to be used to cool pilots in planes with glass domes. Dr. Billingham first proposed air-ventilated suits to cool air crews; however, he quickly found the air systems to be inefficient conductors and so designed a water cooled suit. From these beginnings, the garment was adapted by the United States, developed, and refined into the highly-beneficial multi-purpose technology it is today.

The U.S. Navy first discovered and revamped the British liquid-cooled garments in the 1950's, intending to use them to cool full pressure suits worn by F4 pilots. The Air Force was also interested in the garments to be used in SR71's (Blackbirds). The garments received limited military use, however. They were often problematic and generally not well-suited for their purposes.

NASA TECHNOLOGY

Engineers and scientists at Johnson Space Center were tasked with cooling the astronauts inside the spacesuits which must be worn to protect them from the 250 degree Fahrenheit lunar temperatures. In 1964, Dr. Billingham went to work at Johnson. He discovered that air ventilation was still being used as the cooling method inside the spacesuits. He introduced the water cooled suit he had been working on and proposed it be used inside the spacesuits to cool the astronauts. A team of engineers at Johnson polished and refined the original suit which used a tigon-tubing network encased in a 3-D material that would prevent the delicate tubing from being crushed. The resulting liquid cooled garment successfully maintained the astronauts body temperature at an acceptable level.

Several private sector companies-including, ILC Dover, United Technologies Corporation and Welson - were contracted to contribute to the design, development, manufacture, and integration into the spacesuit of the liquid-cooled garment. ILC Dover ultimately became the prime contractor of the liquid cooled garment used in the NASA spacesuits. They incorporated the developments made at Johnson in the design, development, and manufacture of the liquid-cooled garment for the Apollo program. ILC Dover continually redesigned the garments, improving upon the battery, flow, and patterning for the Skylab and Space Shuttle Programs. In fact, the liquid-cooled garment is still an important part of the space suits worn by today's astronauts.

In the mid-70's, NASA applied their refined liquid-cooled garment technology back to the defense department. The Army and Air Force School of Aerospace Medicine worked closely with NASA contacts on chemical defense systems based on the LCG's. Unfortunately, no complete solution was developed. The Army, however, maintains a large microclimate and personal thermal control program at NADIC Army Research and Development Command. The Navy also has borrowed some LCG's from JSC, pumping hot water through them to warm cold water divers.

SPINOFF TECHNOLOGY

The liquid-cooled garment developed for the astronauts became the basis for development of a family of garments for various terrestrial applications. In the late 60's Ames Research Center became active in liquid cooled garment research for spinoff applications. They determined that the tubing network which provided full body cooling to the astronauts was not suitable for terrestrial applications which generally required localized cooling. Working with a contractor, Accurex Corporation, they developed a patch type system which contained vulcanized flow paths in a urethane coated fabric. In 1971, Accurex produced the first liquid-cooled helmet for helicopter pilots in Vietnam. This was the first spinoff application. ILC Dover also produced a commercial version of the LCG consisting of urethane coated nylon heat sealed together allowing water to flow through it. The unique liquid-cooled garment was subsequently applied to many different uses for industrial, commercial, and medical purposes.

INDUSTRIAL USAGE

In some industrial environments such as chemical and nuclear plants, where technicians must face temperatures as high as 160 degrees fahrenheit, the need for LCG's was readily apparent. In answer to this dilemma, ILC Dover manufactured the "Cool Vest", a lightweight cooling garment designed to eliminate the harmful effects of heat stress. Constructed of urethane-coated nylon, the vest cools the body by circulating chilled water throughout the lining by means of a small battery-powered pump housed in a back pocket. The vest allows unrestricted movement while increasing tolerance time by almost 300%. A related garment, the Vari-Temp Tube Suit, also built by ILC Dover, is a form-fitting undergarment which provides the same cooling process while permitting extended mobility by means of a flow unit attached to an umbilical cord.

AGRICULTURAL USAGE

Another private sector use of LCG's can be found in America's agricultural system. "For the first time in my crop dusting career, I am fresh, alert and without mental pressure," said one farmer taking advantage of Life Support Systems, Inc.'s (LSSI) "Cool Head". LSSI of Mountain View, California was formed in 1980 by Bill Elkins, a researcher at Accurex, when Accurex decided to pursue other endeavors than LCG's. This personal cooling system consists of a lightweight vest unit through which cooling liquid circulates along with a companion cooling headliner. With Cool Head, says LSSI, 40 to 60 percent of body heat storage caused by high temperature can be eliminated and heart rate can be lowered by 50 to 80 beats a minute. Three branches of the military, the U.S. Army, Air Force, and Navy have acquired LSSI's Cool Head for use by those who must work in a heat stress environment.

COMMERCIAL USAGE

Besides serving industrial purposes, LCG's have appeared on the commercial scene in U.S. society. Dr. Bruce Webbon, an Ames researcher, pursued LCG's potential benefits for race-car drivers who face extremely high temperatures in their cockpits. His work involved use of a different configuration-vulcanized flow path in a urethane coated fabric patch in order to even out cooling of the body. Cool suits built upon the original liquid-cooled garment technology have eliminated severe hydration and fatigue experienced by race car drivers. Manufactured by Carlson Personal Cooling Systems and LSSI, cool suits, helmet liners, and body vests have been worn by such notable drivers

as Richard Petty and Dale Earnhardt. In fact, in 1986, the winners of 12 major racing championships used the cooling system.

MEDICAL USAGE

Perhaps, LCG's most extraordinary use has been realized in the medical industry. Along the same lines as the Cool Head application, scientists studied a scalp-cooling system to combat alopecia, hair loss induced by chemotherapy. These systems used during chemotherapy sense the surface temperature of the scalp and report to the controller which regulates the cooling temperature. 63% of patients studied lost virtually no hair thanks to this technology.

In the fight against breast cancer, advancements to the Apollo LCG were applied to a water-cooled, brassiere-like garments, to aid in the detection of the cancer. Since cancerous tissue emits more heat than normal tissue, cooling by the liquid-cooled bra increases the differentiation between the two, improving resolution of a thermograph image.

Johnson Space Center was also contacted by a private citizen who wanted to help a quadriplegic friend who did not have body temperature moderating faculties. With the help of the NASA laboratory, this individual conducted two years of research before developing a special vest attached with an umbilical cord to an igloo ice chest on the back of a wheel chair. This individual disassembled space suits loaned to them by ILC Dover, keeping the parts he needed for his particular development.

Another significant application of NASA technology has improved the lives of many children. A fifteen-year old suffering from a disease know as "burning limb syndrome", a young boy fighting a rare skin disease were just two children who have been fitted with case-specific liquid-cooled garments at Ames Research Center.

LSSI has specialized in the manufacture of special garments for children suffering from lack of natural heat loss mechanisms. The first child assisted by LSSI, Stevie Roper found his LCG after an exhaustive search by his aunt Sarah Moody of Hampton, Virginia. In July of 1986, Ms. Moody contacted the Langley Research Center Technology Utilization Office requesting help for her nephew, a sufferer of Hypohidrotic Ectodermal Dysplasia (HED). Persons with HED do not have sweat glands and therefore cannot dissipate heat at a normal rate. Therefore, any exercise or subjection to high temperatures, elevates body temperature within a range which may cause death.

John Samos and Thayer Sheets of the Technology Utilization Office at Langley referred Ms. Moody to USSI who designed a special suit for Stevie. Ms. Moody then established the HED Foundation which, with the financial support of Po Folks Restaurant franchise, has provided cooling support systems to many children in the past seven years alone. Numerous television shows, newspaper, and magazine articles have praised the work of the Foundation and the incredible LCG's.

LSSI suits have benefitted each child in countless ways. They have provided tolerable support so that each child can enjoy life outside their respective homes, in addition to extracting heat from tissue so as enhance their recovery. Furthermore, the suits have aided in the regulation of other body functions, permitting children to sleep, eat and drink normally.

Doctor's have been amazed at the successful results achieved because of the suits, which have been provided to children suffering from several disorders in addition to HED, including Cystic Fibrosis, Multiple Sclerosis, Severe Burns, and Spinal Bifita.

CONCLUSION

As is obvious, the market for cooling garment systems is very diverse. In 1991, 400 suits were purchased by the Army for use by demolition personnel in the Persian Gulf War. Following the war, LSSI was presented with a Public Service Medal. The company has passed the \$10 million mark in sales of systems for medical purposes. Since 1991, about 300 suits have been sold by LSSI to Multiple Sclerosis patients, where significant beneficial results have prompted sales and MS studies in England, Israel, and Holland.

The liquid-cooled garments technology, was inducted into the United States Space Foundation's Space Technology Hall of Fame in 1993.

KEY DEVELOPMENTS

- 1950's First garments developed by Dr. John Billingham in England
Garments tested by U.S. military
- 1960's NASA obtains, polishes, and refines LCG technology
Contractors are selected to manufacture LCGs for spacesuits
- 1970's ILC Dover produces liquid-cooled garment layer for space suits for Apollo
First spinoff application - pilot helmet liner
Liquid-cooled garments used by military in Vietnam
- 1980's Spinoff applications in industry, agriculture, commercial, and medical sectors
HED Foundation developed formed
- 1990's LCG's used by military in the Persian Gulf War
Hall of Fame nomination and induction